

Indicator: Forest Fragmentation (110)

The amount of forestland in the United States monitored by the USDA Forest Service has remained nearly constant over the past century, but the patterns of human land-use have affected its distribution from one region to another. Forest fragmentation involves both the extent of forest and its spatial pattern, and is the degree to which forested areas are being broken into smaller patches, and pierced or interspersed with non-forest cover.

Forest fragmentation is a critical aspect of the extent and distribution of ecological systems. Many forest species are adapted to either edge or interior habitats. When the degree or patterns of fragmentation change, it can affect habitat quality for the majority of mammal, reptile, bird, and amphibian species found in forest habitats (Fahrig, 2003). As forest fragmentation increases beyond the fragmentation caused by natural disturbances, edge effects become more dominant, interior-adapted species are more likely to disappear, and edge- and open-field species are likely to increase.

This indicator, forest fragmentation, was developed by the USDA Forest Service and has appeared in other recent reports (USDA, 2004; Heinz Center, 2002). The USDA Forest Service's Southern Research Station performed a re-analysis of National Land Cover Data (NLCD), aggregating the four NLCD forest cover classes (coniferous, deciduous, mixed, and wetland forest) into one forest class and the remaining land cover classes into a non-forest class and a "missing" class consisting of water, ice/snow, and bare ground (Riitters, et al., 2002). A model that classifies forest fragmentation based on the degree of forestland surrounding each forest pixel (a square approximately 30 meters on each edge) for various landscape sizes (known as "windows") provides a synoptic assessment of forest fragmentation for the conterminous United States by assessing each pixel's "forest neighborhood" within various distances.

Results are based on three degrees of land cover and five landscape sizes. Degrees of land cover are designated "core" if a subject pixel is surrounded by a completely forested landscape (no fragmentation); "interior" if a subject pixel is surrounded by a landscape that is at least 90% forest; and "connected" if a subject pixel is surrounded by a landscape that is at least 60% forest. These degrees of land cover are not mutually exclusive; a pixel that meets the core criterion also meets the other two. Landscape sizes are based on the number of square pixels surrounding the subject pixel. The five landscape sizes are 5.6 acres (a 5 by 5 pixel square), 18.0 acres (a 9 by 9 pixel square), 162 acres (a 27 by 27 pixel square), 1459 acres (an 81 by 81 pixel square), and 13,132 acres (a 243 by 243 pixel square).

What the Data Show

At every scale, the Forest Service found a majority of the nation's forestland to be "connected" to other forestland, appearing as landscapes dominated by forest (Figure 110-1). However, the data for "interior" and "core" forests suggest that fragmentation is extensive, with few large areas of complete, unperforated forest cover. At every scale, the Forest Service found a majority of forestland to be "connected" to other forestland, but the data for "interior" and "core" forests show that fragmentation affects much of the nation's forestland (Figure 110-1). In small landscape areas of 5.6 acres, 68.7% of forest pixels are at least 90% surrounded by other forestland, but in larger areas of 13,132 acres, the percentage drops to 24.2%. The percentage of forest pixels surrounded by a fully forested landscape drops from 56.5% in the smallest areas (5.6 acres) to 9.9% in areas of 162 acres, and to zero for large, 13,132-acre areas. Forestland in the eastern U.S. is slightly less fragmented than forestland in the western U.S. (USDA, 2004).

Indicator Limitations

- The dataset uses the NLCD, which is based on an inventory of land cover circa 1992. No trends over time can be established, and the satellite imagery is more than a decade old.
- NLCD data do not include land cover classes for Hawaii or Alaska, which accounts for about one out of every six acres of forestland in the United States
- Not every non-forest NLCD land cover class was aggregated as “non-forest.” In this analysis, the “other” NLCD classes (water, ice/snow, bare ground) were treated as missing values and were not considered a reflection of forest fragmentation. Together, this “missing” class covers about 60 million acres.
- Because the non-forest land cover classes were aggregated, the contributions of specific types of non-forest land cover to forest fragmentation cannot be calculated, making it difficult to distinguish between natural and anthropogenic fragmentation.
- Fragmentation by roads was only partly captured by basing the analysis on the NCLD maps, which show some roads but not all. Not including road maps probably underestimates fragmentation on most public forestlands (Riitters et al., 2004).

Data Sources

Riitters, K.H. 2003. Report of The United States on the Criteria and Indicators for the Sustainable Management of Temperate and Boreal Forests, Criterion 1: Conservation of Biological Diversity, Indicator 5: Fragmentation of Forest Types. Final Report. February 1, 2003.

References

Fahrig, L. 2003. Effects of habitat fragmentation on biodiversity. *Annu. Rev. Ecol. Evol. Syst.* 34: 487–515.

Riitters, K.H., Wickham, J.D., O'Neill, R.V., Jones, K.B., Smith, E.R., Coulston, J.W., Wade, T.G., Smith, J.H. 2002. Fragmentation of Continental United States Forests. *Ecosystems* 5:815-822. http://www.srs.fs.usda.gov/pubs/ja/ja_riitters002.pdf.

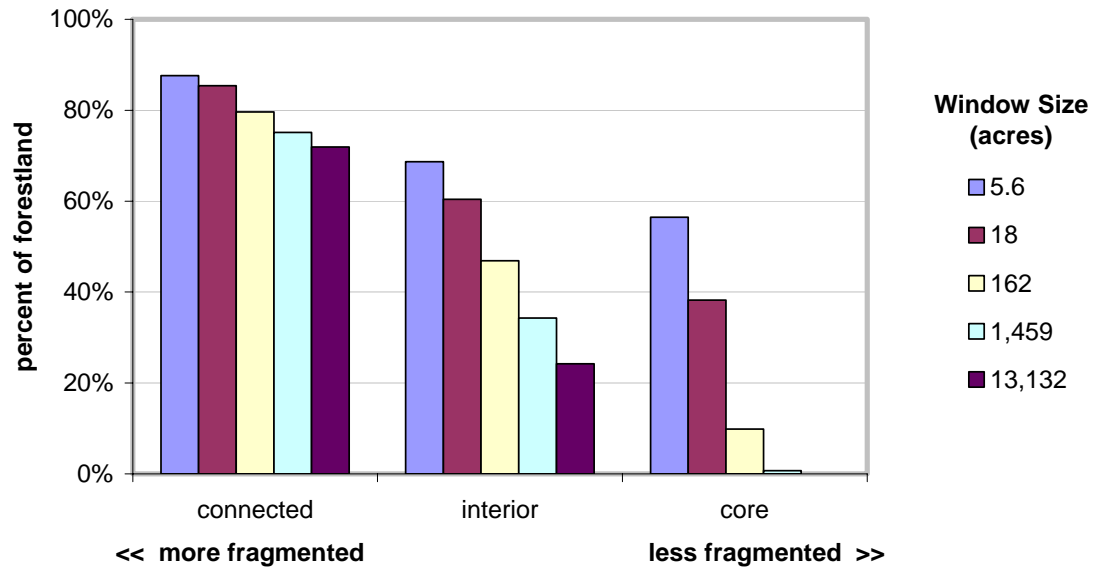
Riitters, K., Wickham, J., and Coulston, J. 2004. Use of road maps in national assessments of forest fragmentation in the United States. *Ecology and Society* 9(2):13. <http://www.ecologyandsociety.org/vol9/iss2/art13/>.

The H. John Heinz III Center for Science, Economics, and the Environment. 2002. The State of the Nation's Ecosystems: Measuring the Lands, Waters, and Living Resources of the United States. New York, NY: Cambridge University Press, September 2002. Forest Fragmentation and Pattern Indicator: <http://www.heinzctr.org/ecosystems/forest/frgmnt.shtml>.

USDA Forest Service. 2004. National Report on Sustainable Forests—2003. FS-766. <http://www.fs.fed.us/research/sustain/>.

Graphics

Figure 110-1. Patterns of Forest Fragmentation, 1992



connected = surrounded by at least 60% forestland

interior = surrounded by at least 90% forestland

core = surrounded by 100% forestland

R.O.E. Indicator QA/QC

Data Set Name: FOREST PATTERN AND FRAGMENTATION

Indicator Number: 110 (89604)

Data Set Source: Riitters, K.H., Wickham, J.D., O'Neill, R.V., Jones, K.B.,

Data Collection Date: Based on 1992 NLCD

Data Collection Frequency: NA

Data Set Description: Examines status and trends of forest fragmentation

Primary ROE Question: What are the trends in the extent and distribution of the Nation's ecological systems?

Question/Response

T1Q1 Are the physical, chemical, or biological measurements upon which this indicator is based widely accepted as scientifically and technically valid?

Yes. The indicator is based on an aggregate forest land cover class derived from NLCD land cover classes, which provide the only synoptic classification of land cover in the conterminous United States. Each pixel of forest land cover is assessed for degree of fragmentation within five landscape (window) areas, based on the amount of forest and non-forest land within a specific surrounding area. Units of measurement are the percent of forested landscape (within a specific landscape area of the subject forest pixel).

Uncertainty measurements are not available at a national level. The methodology is best described in the following article: Riitters, K.H., Wickham, J.D., O'Neill, R.V., Jones, K.B., Smith, E.R., Coulston, J.W., Wade, T.G., Smith, J.H. 2002. Fragmentation of Continental United States Forests. *Ecosystems*. 5:815-822.

http://www.srs.fs.usda.gov/pubs/ja/ja_riitters002.pdf.

T1Q2 Is the sampling design and/or monitoring plan used to collect the data over time and space based on sound scientific principles?

Yes. NLCD data has gone through extensive peer review and QA/QC. The methodology used by the researchers to assess forest fragmentation re-analyzes NLCD data, and assesses degree of forest fragmentation based on an aggregate forest land cover class.

T1Q3 Is the conceptual model used to transform these measurements into an indicator widely accepted as a scientifically sound representation of the phenomenon it indicates?

Yes. The development of the authors' fragmentation index allows for the inclusion of both the specific forest pixel and the surrounding landscape in calculating the degree of forest fragmentation. Fragmentation is thus viewed as a property of the landscape that contains the forest, in contrast to a view of fragmentation as a property of the forest itself. From this model, the data are able to show that forest is generally connected over large regions, but that fragmentation is so pervasive that edge effects influence ecological processes on most forested lands.

T2Q1 To what extent is the indicator sampling design and monitoring plan appropriate for answering the relevant question in the ROE?

Analysis of the sampling design and monitoring plan for NLCD data are included in the Land Cover (324) indicator metadata form. Aggregating NLCD forest cover classes into one forest cover class allows for analysis of forest fragmentation caused by non-forest classes of land cover. NLCD data provides 30 meter resolution, allowing for accurate classification of forest and non-forest cover. The indicator was included in the Ecological Condition Chapter of the 2003 Report on the Environment

<http://www.epa.gov/indicators/roe/pdf/tdEco5-2.pdf>.

T2Q2 To what extent does the sampling design represent sensitive populations or ecosystems? The database is based on a synoptic coverage of the U.S. and represents an aggregation of various forest classes. Sensitive populations and ecosystems are not specifically identified.

T2Q3 Are there established reference points, thresholds or ranges of values for this indicator that unambiguously reflect the state of the environment?

The study authors developed a fragmentation index for each of five specific landscape sizes. "Core" signifies that 100% of the surrounding landscape area consists of forest land; that is, forest fragmentation does not exist. "Interior" and "connected" correspond to 90% and 60%, respectively, of surrounding landscape area being forested.

T3Q1 What documentation clearly and completely describes the underlying sampling and analytical procedures used?

The analytical procedures are described in Riitters, K.H., Wickham, J.D., O'Neill, R.V., Jones, K.B., Smith, E.R., Coulston, J.W., Wade, T.G., Smith, J.H. 2002. Fragmentation of Continental United States Forests. Ecosystems. 5:815-822.

http://www.srs.fs.usda.gov/pubs/ja/ja_riitters002.pdf.

T3Q2 Is the complete data set accessible, including metadata, data-dictionaries and embedded definitions or are there confidentiality issues that may limit accessibility to the complete data set?

The complete data set and metadata for the fragmentation model are available: see Riitters, K.H. 2003. Report of The United States on the Criteria and Indicators for the Sustainable Management of Temperate and Boreal Forests, Criterion 1: Conservation of Biological Diversity, Indicator 5: Fragmentation of Forest Types. Final Report. February 1, 2003. Related reports are available at

http://www.srs.fs.usda.gov/pubs/ja/ja_riitters002.pdf (by Kurt Riitters, the author of the main study on which this indicator is based) and

<http://www.heinzctr.org/ecosystems/forest/frgmnt.shtml> (by the Heinz Center).

T3Q3 Are the descriptions of the study or survey design clear, complete and sufficient to enable the study or survey to be reproduced?

Yes. The model used to quantify forest fragmentation as described is clear enough to allow for replication. NLCD data, broken down by class, are available to the public.

T3Q4 To what extent are the procedures for quality assurance and quality control of the data documented and accessible?

QA/QC of NLCD data is extensive and well documented (<http://landcover.usgs.gov/accuracy/index.asp>). Descriptions of the QA/QC for the analytical procedures employed in developing the forest fragmentation are not readily available.

- T4Q1** Have appropriate statistical methods been used to generalize or portray data beyond the time or spatial locations where measurements were made (e.g., statistical survey inference, no generalization is possible)?

As the fragmentation model is based on forest land cover classes from the NLCD, a one-time inventory (and not sample) of land cover in the conterminous United States, generalization via statistical methods is unnecessary and unfeasible.

- T4Q2** Are uncertainty measurements or estimates available for the indicator and/or the underlying data set?

For the eastern seaboard, the forest versus non-forest classification accuracy of the NLCD is 86% (based on commission error) and 94% (based on omission error). Estimates for other regions are currently being developed. Yang L, Stehman SV, Smith JH, Wickham JD. 2001. Thematic accuracy of MRLC land cover for the eastern United States. *Remote Sensing Environment*, 76:418-22.

- T4Q3** Do the uncertainty and variability impact the conclusions that can be inferred from the data and the utility of the indicator?

No. NLCD satellite imagery permits a consistent assessment of forest fragmentation for the conterminous United States at unprecedented spatial resolution. The accuracy of NLCD forest classification suggests that forestland can be accurately determined from satellite imagery, and analyzed within a larger landscape area.

- T4Q4** Are there limitations, or gaps in the data that may mislead a user about fundamental trends in the indicator over space or time period for which data are available?

Alaska accounts for about one out of every six acres of forestland in the United States according to the Forest Inventory Analysis, so the inability to assess forest fragmentation in Alaska detracts from the ability to provide a national picture. It is important to clarify that this indicator does not apply to Alaska. In developing the fragmentation model, the authors chose to exclude the water and bare rock NLCD land cover classes for their aggregate non-forest land cover class (they were treated as missing values), so these were not included when calculating forest fragmentation. The reasons for this were not entirely explained.